Landscape and sustainability: Three residential college buildings in the tropics

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ABSTRACT *Three residential colleges located in a university campus at the capital city of Kuala Lumpur and built in different decades were selected for landscape studies with respect to species and position of the trees, as well as the effects of the current landscapes as a shelter in reducing solar radiation on buildings, as a pre-assessment for the Low Carbon Cities Framework (LCCF) and assessment system. These landscape settings were carefully studied through on-site observation. The name and location of the mature trees were redrawn and visualised with standard normal photographs. These studies revealed that the old residential college landscape is dominated by tropical forest trees which are able to provide a significant shade to the buildings and become a sustainable carbon sequestrations tool. For low maintenance and fast growing effect, palms and hybrid fruit trees were extensively cultivated in the new residential colleges.*

KEY WORDS: residential college, landscape, low carbon cities framework (LCCF), sustainable development, tree shade effect.

Introduction

Urbanisation is a dramatic increase in the number of populations that impulsively magnifies the microclimate and global carbon cycle. The urban or sub-urban area develops rapidly to meet the population needs. There are numerous changes on the land physical surface from natural or semi-natural ecosystems to man-made structures which are typically darker surfaces while emitting large amounts of CO_2 due to energy consumption and transportation (Akbari et al. 2001; Sani and Sham 2007; Chen et al. 2011; Strohbach et al. 2012). The rapid urbanization and massive infrastructure developments indirectly affect the urban plant diversity and landscape patterns (Jim and Chen (2009). Hence, numerous researches on the landscape has been extensively done with the aim to achieve sustainable development and a healthier environment especially in urban areas (Grazuleviciute-Vileniske

2008; Matsuoka 2010; Selman 2010; Ling and Dale 2011; Thompson 2011; Zheng et al. 2011).

Based on a case study in Guangzhou, China, He and Jia (2007) proposed a framework of three dimensions for implementing sustainable concepts in residential landscapes in the urban context, which includes ecology, socioeconomic and cultural aspects. Then, Lau and Yang (2009) have discussed introducing the natural space; which contain prominent amounts of real nature content such as green vegetation, flower and water, and its potential role with the objective of creating a health-supportive and sustainable campus environment through four design strategies. 1. Enhance visual connections of the natural green spaces and their surroundings, 2. Manipulate space morphology to improve user perception, 3. Careful tree selection and, 4. Use of green roof gardens and green walls. These four strategies are relevant to the area with compact and high-density profiles when the existing green spaces do not encourage large groups of people to access them and recently acknowledged as the common phenomenon in urban areas.

The presence of a landscape with green trees provides better environments than open sky (Monteiro and Alucci 2009). The tree canopy has a significant filtration capability which contributes to the reduction of terrestrial radiation, cooling the ground surfaces by capturing more latent heat, reducing air temperature by promoting more evapotranspiration, and effectively improves the outdoor thermal comfort especially in open spaces of the tropical climate region (Shahidan et al. 2010). On average, trees can reduce 38% of the total solar radiation received by residential building rooftops and strong correlations were found between measures of tree structures (average height, tree height variability, and normalized tree volume) and intercepted direct radiation in the summer (Tooke et al. 2011). The landscape with specific species of tree in urban areas can play a role in carbon sequestration by fixing CO_2 during photosynthesis and storing the excess carbon through its biomass (Nowak and Crane 2002; Gratani and Varone 2006; 2007; Tratalos et al. 2007; Hutyra et al. 2011; Strohbach and Haase 2012).

In Malaysia, the landscape was highlighted as an element to support holistic sustainable development. The ‘Urban Greenery and Environmental Quality’ is one of the performance criteria under ‘Urban Environment’ element of the Low Carbon Cities Framework (LCCF) and assessment system. The LCCF is an extension of Malaysia National Green Technology Policy to contribute towards the Prime Minister’s commitment at United Nations Climate Change Conference Copenhagen (COP15). There is a conditional voluntary target to reduce carbon emission intensity of up to 40 per cent of Gross Domestic Product (GDP) as compared to 2005 levels, where Greenhouse Gas (GHG) reduction approach is used in this document (KeTTHA 2011).

Generally, there are four key elements of LCCF and its assessment system namely ‘Urban Environment’, ‘Urban Transport’, ‘Urban Infrastructure’ and ‘Building’, as shown in detail in Table 1.

Table 1. The breakdown of 13 performance criteria and 35 sub-criteria of LCCF (with reference to KeTTHA 2011)

Urban Environment	*UE 1*	*Site Selection*
	1-1	Development with defined urban footprint
	1-2	Infill development
	1-3	Development within transit nodes and corridor
	1-4	Brownfield and greyfield redevelopment
	1-5	Hill slope development
	UE 2	*Urban Form*
	2-1	Mixed-use development
	2-2	Compact development
	2-3	Road and parking
	2-4	Comprehensive pedestrian network
	2-5	Comprehensive cycling network
	2-6	Urban Heat Island (UHI) effect
	UE 3	*Urban Greenery and Environmental Quality*
	3-1	Preserve natural ecology, water body and biodiversity
	3-2	Green open space
	3-3	Number of trees
Urban Transport	*UT1*	*Shift of Transport Mode*
	1-1	Single Occupancy Vehicle (SOV) dependency
	UT2	*Green Transport Infrastructure*
	2-1	Public transport
	2-2	Walking and cycling
	UT3	*Clean Vehicles*
	3-1	Low carbon public transport
	3-2	Low carbon private transport
	UT4	*Traffic Management*
	4-1	Vehicle speed management
	4-2	Traffic congestion and traffic flow management
Urban Infrastructure	*UI 1*	*Infrastructure Provision*
	1-1	Land take for infrastructure and utility services
	1-2	Earthwork management
	1-3	Urban storm water management and flood mitigation
	UI 2	*Waste*
	2-1	Construction and Industrial Waste Management
	2-2	Household Solid Waste Management
	UI 3	*Energy*
	3-1	Energy optimisation
	3-2	Renewable energy
	3-3	Site-wide district cooling system
	UI 4	*Water Management*
	4-1	Efficient water management
Building	*B 1*	*Low Carbon Buildings*
	1-1	Operational energy emissions
	1-2	Operational water emissions
	1-3	Emission abatement trough retrofitting
	1-4	Building orientation
	B 2	*Community Services*
	2-1	Shared facilities and utilities within building

Under these four key elements, there are 13 performance criteria and 35 sub-criteria to help stakeholders to comprehend the carbon footprint, as well as to assist in taking the applicable reduction measures (KeTTHA 2011). Focusing on the performance criteria ‘UE 3 - Urban Greenery and Environmental Quality’, carbon emission reference and recommendations for carbon emission reduction were extensively explained in Table 2.

Table 2. Details of performance criteria UE 3 – Urban Greenery and Environmental Quality (with reference to KeTTHA 2011)

Sub-criteria	Intent	Carbon emission reference	Recommendation for carbon emission reduction
UE 3-1 Preserve natural ecology, water body and biodiversity	To provide natural restoration of carbon by improving urban biodiversity through preservation and conservation of natural environment and water bodies or wetlands.	1. A tropical forest absorbs 5.5 kg of CO_2/year. 2. 1hectare of tropical forest absorbs 4.3 to 6.5 tCO_2/year. 3. 1hectare of tropical wetlands absorbs 1.48 tCO_2/year. 4. 1 tree absorbs approximately 1,000 kg of CO_2. 5. 1 acre of trees stores 2,600 kg of carbon/year (where tree cover for an urban area is about 204 trees/acre. For forest it is about 480 trees/acre)	1. Incorporate green and blue corridors in development plans. 2. Identify possible sites for environmental sensitive protection. 3. Preserve forests, wetlands and water bodies. 4. Enhance urban biodiversity through the enhancement of existing habitats and creation of new habitats.
UE 3-2 Green open space	Increase percentage of green open space within cities or townships.		1. Gazette green open space. 2. Preserve more forest and green spaces. 3. Increase percentage of tree coverage of the total land area. 4. Incorporate requirements for specific green areas near office blocks, along the street and within residential areas through tree planting. 5. Plant fast growing, decorative and low-maintenance types of vegetation.
UE 3-3 Number of trees	Increase percentage of tree coverage within cities or townships.		1. Incorporate a tree planting programme and campaign. 2. Increase percentage of tree coverage of the total land area. 3. Increase the number of trees near office blocks, along streets and within residential areas. 4. Encourage planting of fast growing, decorative and low maintenance types of vegetation. 5. Organise landscaping competition among schools to promote the "go green" culture among the younger generation (students).

Regarding the sub-criteria UE 3-2 Green open space and UE 3-3 Number of trees, there are two relevant carbon factors where the environmental quality can be improved through strategic plans. There are, 1. Increase in green open space/trees resulting in an increase in carbon sequestration, and 2. The types of trees and vegetation determine the quantity of CO_2 being sequestered (KeTTHA 2011). Nevertheless, the rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth and where the tree is planted (Gratani and Varone 2005), whilst it is the greatest in a large tree with relatively long life spans (Nowak et al. 2002). Then, the amount of CO_2 sequestered in a tree can be estimated given the tree's age, trunk diameter and height (KeTTHA 2011).

The aim of this work is to study the landscapes of three residential colleges which were built in three different decades, with respect to species and position of the trees. The landscape setting of residential colleges and its effects as a shelter in reducing solar radiation on the building were studied in general. Indirectly, it becomes a pre-assessment of the approaches of the LCCF and assessment systems under the performance criteria of 'UE3 - Urban Greenery and Environment Quality'. Thus, this is 'One-System Approach' which is only mitigated a selected sub-criteria in the LCCF when not all the criteria in the LCCF will be considered and mitigated (KeTTHA 2011).

Research method and its application

Residential college description

Three residential colleges with different years of establishment were chosen in this study, namely, Dayasari Residential College (CS-A), Kinabalu Residential College (CS-B) and Ungku Aziz Residential College (CS-C). With different configurations and layout, all these residential colleges are located within the University of Malaya campus in the capital city of Kuala Lumpur and provide residences for more than 2,400 students including local and international students. Table 3 shows the description of these three residential colleges.

CS-A is the oldest residential college, established in 1966 and is designed with an internal courtyard arrangement, which clearly differs from CS-B. CS-B which was established in 1985 with a linear arrangement. As the new residential college, established in 1997, CS-C shows some evolution in terms of building design as it has been arranged with an internal courtyard and balcony. With respect to enclosures and façade, all residential colleges are designed with glare protection with adjustable and fixed ventilation as an option. Each residential college is made up of one administrative block and four to five residential blocks. All administrative offices were equipped with air conditioned by using split unit systems, while all the residential units/rooms in the residential blocks were non- air conditioned and provided with a ceiling fan and a fluorescent lamp.

Landscape studies

The buildings' drawings, which include a site plan, architectural and landscape drawings, were the main source of data for the landscape setting studies. Site observations on each residential college were also carried out in order to gauge actual conditions, since most of the drawings were drawn 30 to 40 years ago, and since then, numerous renovations and add-ons have been carried out.

Table 3. Description of the three residential colleges

Characteristics	Residential colleges		
	CS-A	CS-B	CS-C
Year established	1966	1985	1997
Form of building	Low-rise	Low-rise	Low-rise
Building layout & arrangement	Courtyard arrangement	Linear arrangement	Courtyard arrangement
Orientation to sun path	N-S	N-S, NW-SE & NE-SW	N-S & W-E
Shape of the building	Rectangle	Rectangle	L-shape
Wind direction	SW	SW	SW
Floor level (excluding GF)	3	3	3
Capacity / No. of residents	885	765	897
Total area (m^2)	43,185.06	32,806.00	26,766.14
Total built up area (m^2)	16,971.02	9,213.63	11,250.44
Total floor area (m^2)	18,212.51	11,274.23	34,305.32
Density (No. of residents/m^2)	0.049	0.062	0.026
EEI (kWh/m^2/year)	34.52	83.96	24.23
Typical room's floor area (m^2)	16.35	14.78	20.00
Typical room volume (m^3)	45.78	47.30	57.40
Window area (m^2)	6.41	3.34	Type A : 1.65 / Type B : 4.12
Window to wall ratio	0.66	0.38	Type A : 0.14 / Type B : 0.36
Operable window area (m^2)	4.20	3.34	Type A : 1.10 / Type B : 2.75
Operable window to wall ratio	0.43	0.38	Type A : 0.1 / Type B : 0.24
Window design	Centre pivot & awning	Louver	Casement & Turn window
Window location	N-S	N-S, NW-SE & NE-SW	N-S & W-E
Ratio of soft and hard landscape	61:39	72:28	58:42
Biotope Area Factor (BAF)*	0.607	0.719	0.580

Note:

N - North, E - East, S - South, W - West, NW - Northwest, NE - Northeast, SE - Southeast, SW - Southwest
EEI - Energy efficiency Index

$$* \text{ BAF} = \frac{Ecologically\ effective\ surface\ area}{Total\ and\ area}$$

(with reference to Dizdaroglu et al, 2009; Kazmierczak and Carter 2010; Roehr and Kong 2010)

The landscape setting of each residential college was re-drawn to illustrate precisely the species and location of the mature trees which provide a significant shade to the buildings. The standard normal photographs were also taken on bright days to analyse the effects of landscape as a shelter in reducing sunlight radiation and penetration in the buildings. The standard normal photographs are an appropriate tool for measuring certain variables in landscape assessment instead of in situ landscape and panoramic photographs (Sevenant and Antrop (2011).

Results and discussion

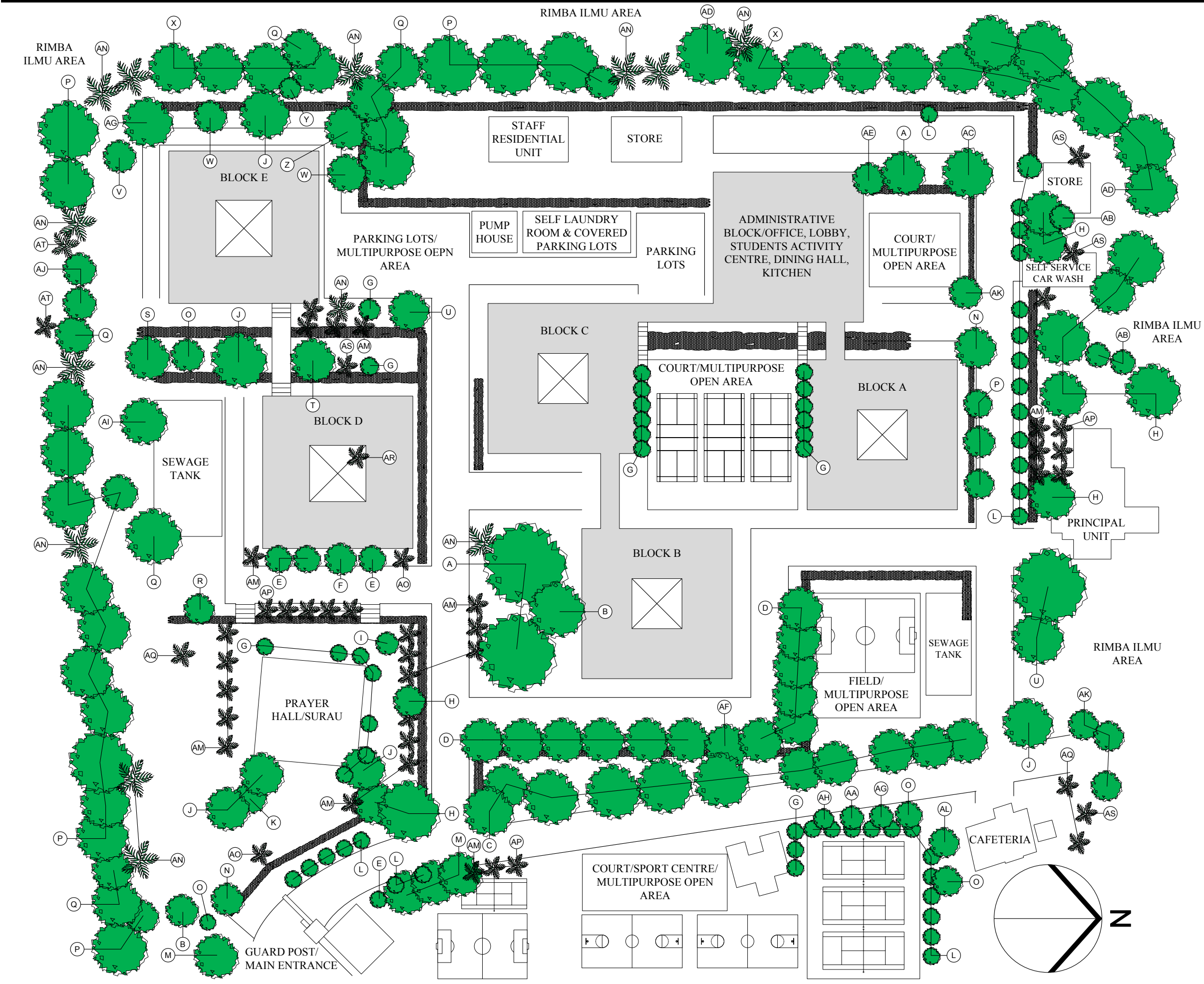
The landscape of CS-A

CS-A has the second largest ratio of soft and hard landscape area, which is 61:39 with 0.607 of Biotope Area Factor (BAF), compared to other two residential colleges. Nevertheless, most of the trees in the CS-A landscape is well matured and the tree canopies cover the ground and also give shade to the residential building from maximum sunlight penetration. The CS-A is surrounded by a highly vegetated area with high diversity of trees as located next to the foothill of Rimba Ilmu, tropical botanical garden (University of Malaya 2005) as shown in Figure 1 and 2.

The presence of *Cinnamomum sp.*, *A. champeden*, *N. lappaceum*, *P. longifolia*, *D. suffruticosa*, *M. malabathricum* and *M. gigentea* significantly reduces the late afternoon solar radiation to Block E by filtering, reflecting and scattering the sunlight (Figure 2a). Whereas, the presence of *C. inophyllum* and *M. atropurpurea* in one row shades Block B from excessive morning sunlight (Figure 2b). The same situation also occurs in Block D with the presence of *C. nucifera*, *J. chinensis*, *C. lanceolatus* and *C. lakka* (Figure 2c). Unfortunately, it only covers a certain level and area especially the ground floor and balcony. In Block C, which is located at a higher altitude, the east wall is freely exposed to morning sunlight even though there is a green area at the front of it (Figure 2d).

Moreover, a row of *P. pterocarpum*, and *L. floribunda* at the north orientation of Block A (Figure 2e), and a line of *M. atropurpurea*(Figure 2f) and a dense canopy of *P. indicus* (Figure 2g) at north and south orientation of Block B, directly moderates solar radiation which reflects from the tarmac. With a dense canopy of trees, it creates a recreation ground for the residential community while provides a shelter for the wildlife; such as Myna bird, monkey and jungle fowl, and other small trees to grow (Elevith 2006). Then, the higher populations of wildlife and tree diversity are also can be seen in the north, south, and west of CS-A which is dominated by *Bambusa sp.*, *M. gigente*, *E. guineensis*, *D. suffruticosa*, and *Calameae sp.* (Figure 2h&i).

Although there is a row of trees which consist of *N. lappaceum*, *Shorea sp.*, and *G. manggostana*, the height and canopy of these trees are not able to be a shelter in reducing solar radiation at the east orientation of Block E especially at the higher level (Figure 2j). The same condition also occurs at Block A when shadow of *C. inophyllum* covers the adjacent field (Figure 2k)., With the presence of *T. orientalis* as a border between the court and Block A, as well as Block C, the solar radiation from the direct reflection of sunlight on the court was present especially during the afternoon (Figure 2l).



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No.	Botanical name	Common name	Height (m) [1]	Form [2]	Symbol
Trees					
1.	*Pterocarpus indicus*	Angsana, Sena	30	Spreading	A
2.	*Ficus benjamina*	Weeping Fig, Benjamin's Fig, Ficus Tree, Waring, Beringin, Ara Beringin	24	Dropping	B
3.	*Calophyllum inophyllum*	Ballnut, Penaga Laut, Paku Achu	18	Round	C
4.	*Millettia atropurpurea*	Purple Millettia,Tulang Daeng, Jenaris	30	Conical	D
5.	*Juniperus chinensis*	Blue Juniper	10-15	Conical	E
6.	*Callistemon lanceolatus*	Bottlebrush	< 10	Conical	F
7.	*Thuja orientalis*	Thujas, White Cedar, Yellow Cedar	< 10	Conical	G
8.	*Durio zibethinus*	Durian	25	Spreading	H [3]
9.	*Syzgium samarangense*	Wax Apple, Love Apple, Java Apple, Water Apple, Mountain Apple, Jambu Air	12	Conical	I [3]
10.	*Nephelium lappaceum*	Rambutan	15	Spreading	J [3]
11.	*Microcos blattaefolia*	Chenderai, Bunsi	-	Spreading	K
12.	*Mesua ferrea*	Ceylon Ironwood, Penaga, Penaga Lilin, Ironwood Tree, Lenggapus	20	Conical/ Round	L
13.	*Peltophorum pterocarpum*	Yellow Flame, Batai Laut	20	Spreading	M
14.	*Lagerstroemia floribunda*	Kedah Bungor, Bungar, Bungor	18	Conical	N
15.	*Shorea sp.*	Temak, Seraya, Meranti Sarang Punai, Kepong, Meranti Sengkawang	30-50	Round	O
16.	*Bambusa sp.*	Bamboo, Buluh	12-30	-	P

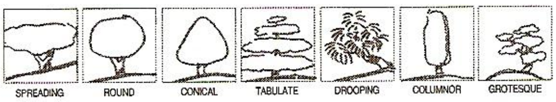
Figure 1. Landscape plan of CS-A (with reference to Said et al. 2004; LaFrankie 2010; Jabatan Perangkaan Bandar dan Desa 1995).

No.	Botanical name	Common name	Height (m) [1]	Form [2]	Symbol
Trees					
17.	*Macaranga gigentea*	Elephant's Ear, Giant Mahang, Telinga Gajah, Kubin	20	Spreading	Q
18.	*Alstonia angustifolia*	Pulai	25	Spreading	R
19.	*Garcinia manggostana*	Mangosteen, Manggis, Mesetor, Sementah, Semetah.	18	Conical	S [3]
20.	*Hopea odorata*	Merawan Siput Jantan, Chengal Pasir, Chengal Kampung	30	Conical	T
21.	*Mimusops elengi*	Spanish Cherry, Medlar, Bullet Wood, Tanjong, Mengkulah, Mengkulang, Bakul	12	Round	U
22.	*Sambucus javanica*	Javanese Elder,Kerak Nasi	5	Spreading	V
23.	*Artocarpus champeden*	Cempedak	15	Conical	W [3]
24.	*Dillenia suffruticosa*	Simpoh Ayer	15	Round	X
25.	*Melastoma malabathricum*	Singapore Rhododendron, Senduduk	5	Spreading	Y
26.	*Polyalthia longifolia*	Ashoka Tree, Cemetery Tree, Mempisang	18	Conical	Z
27.	*Michelia alba*	White Chempaka, Cempaka Putih	23	Conical	AA
28.	*Phyllanthus acidus*	Malay Gooseberry, Otaheiti Gooseberry, Ceremai, Chermai.	10	Spreading	AB
29.	*Hymenaea courbaril*	West Indian Locust Tree, South American Locust, Stinking Toe, Old Man's Toe	33	Round	AC
30.	*Hevea brasiliensis*	Rubber Tree, Getah	44	Round	AD
31.	*Artocarpus heterophyllus*	Jackfruit, Nangka	17	Conical	AE [3]
32.	*Adananthera pavonina*	Barbados pride, Coral wood, Saga, Suga	20	Round	AF
33.	*Cinnamomum sp.*	Wild Cinnamomum, Kayu Manis, Medang Wangi	12-15	Round	AG
34.	*Mangifera indica*	Indian Mango, Mangga, Mempelam, Pauh	27	Conical	AH [3]
35.	*Melia sp.*	Nim Tree, Mindi Kecil, Persian Lilac, China Berry, Sentang, Setan, Setang	10-50	Spreading / Round	AI
36.	*Piper aduncum*	Spiked Pepper, Menuda	7	Spreading	AJ
37.	*Ravenala madagascariensis*	Traveller's Tree, Traveller's Palm, Pisang Kipas	7	-	AK
38.	*Xanthophyllum sp.*	Minyak Berok, Sesyor, Minyak Berok Laut	25-30	Spreading	AL
Palms					
39.	*Areca catechu*	Betelnut Palm, Pinang	>9	-	AM
40.	*Elaeis guineensis*	African Oil Palm, Kelapa Sawit	>9	-	AN
41.	*Cocos nucifera*	Coconut, Kelapa	> 9	-	AO
42.	*Cyrtostachys lakka*	Sealing Wax Palm, Pinang Merah.	3-9	-	AP
43.	*Caryota mitis*	Clustered Fish Tail Palm, Rabok, Beridin, Dudok	3-9	-	AQ
44.	*Licuala grandis*	Fan Palm, Palas Kipas	<3	-	AR
45.	*Chrysalidocarpus lutescens*	Butterfly Palm, Area Palm, Golden Fruit Palm	<3	-	AS
46	*Calameae sp.*	Rattan, Rotan	1-2	-	AT

Note:

1 Typical/Average matured height

2



3 Fruit tree

Figure 1, continued.

a). The presence of *Cinnamomum sp.*, *A. champeden*, *N. lappaceum*, *P. longifolia*, *D. suffruticosa*, *M. malabathricum* and *M. gigentea* at the west of Block E

b).A row of *C. inophyllum* and *M. atropurpurea* at the east of Block B

c).A row of *C. nucifera*, *J. chinensis*, *C. lanceolatus*, and *C. lakka*

d).Block C is freely exposed to morning sunlight

e).A row of *P. pterocarpum* and *L. floribunda* at north orientation of Block A

f).A line of *M. atropurpurea*

Figure 2. Landscape images of CS-A

g).A dense canopy of *P. indicus*

h).The higher plant diversity which dominated by *Bambusa sp.*, *M. gigente*, *E. guineensis, D. suffruticosa* and *Calameae sp.*

i).The higher plant diversity which dominated by *Bambusa sp.*, *M. gigente*, *E. guineensis, D. suffruticosa* and *Calameae sp.*

j).The low height and small canopy of *N. lappaceum*, *Shorea sp.* and *G. manggostana*

k).The shadow of *C. inophyllum* is only covering the adjacent field, not reaching to Block A

l).A row of *T. orientalis* as a border between court and Block A; as well as Block C

Figure 2, continued.

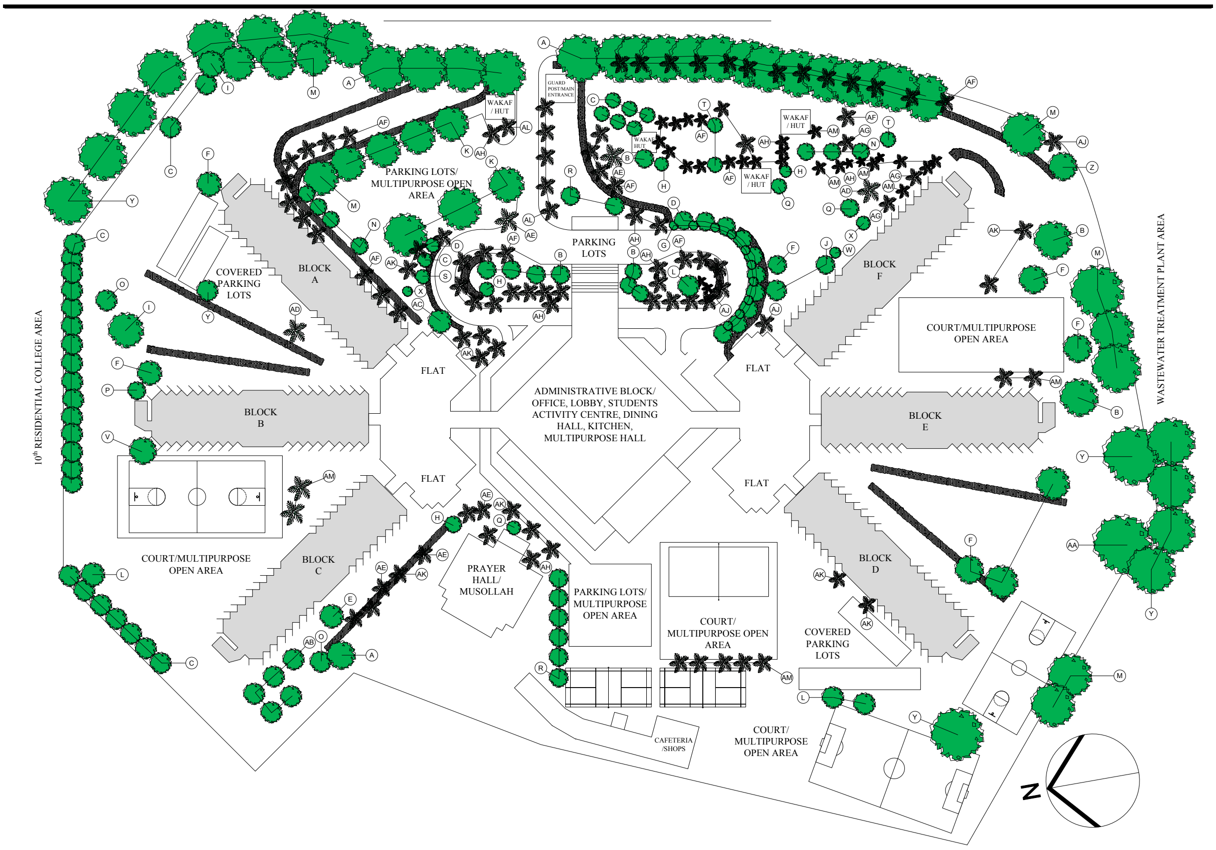
Landscape of CS-B

As located in hillside areas, not so many big trees were planted due to safety issues. Even though, CS-B was the greenest with 72% of soft landscape area and 0.719 of BFA compared to CS-A and CS-C. Most areas with the potential for landslides were planted with grass, *Paspalumconjugatum*, small decoration trees, fruit trees and palms (Figure 3 & 4).

Generally, the landscaping of CS-B was not intended to give shading effects to the residential building from maximum sunlight penetration. Most of the areas between residential buildings were either built with hard surface structures or planted with small fruit trees and palms. There is a tennis court between Block E and Block F while a basketball court between the Block B and Block C (Figure 4a). At the back of Block A and Block D, there is covered parking lots for motorcycles. In generating a typical scene of the village house, *S. samarangense* were planted between Block A and B, Block D and E (Figure 4b) while a row of *V. merrilli* and *P. macarthurii* were planted in certain areas around the sports court (Figure 4c). On reducing sunlight penetration and heat radiation, CS-B is dependent on the shading effect of adjacent buildings and slopes (Figure 4a). A row of *C. lakka* and *P. longifolia* along with Block A (Figure 4d), and *C. nucifera* together with *P. macarthurii*, *D. zibethinus* and *P. indicus* by the side of Block C (Figure 4e) is incapable of providing a full shelter from the direct west-east sunlight penetration. There is also a row of *C. mitis*, *V. merrilli*, *Citrus sp.*, *P. granatum* and *P. guajava* at the side of Block F (Figure 4f). Nevertheless, some part of Block A and Block E especially at the end of the block is shaded with a row of *D. suffruticosa* and *A. auriculiformis* which was planted on the outside of CS-B area at a higher altitude (Figure 4g).

For a boundary, a row of *J. chinensis* were planted on the north area (Figure 4h), *D. suffruticosa* and *A. auriculiformis* at the south area (Figure 4i). Whilst, *P. indicus* and *C. lakka* in the east area (Figure 4j), which plays a role in soil conservation when the tree canopy absorbs the impacts of rain while its roots help retain the water in the soil (Thomson 2006). Indirectly, it also provides a shelter from the sun for the recreational area nearby which is dominated by palm trees.

A role of trees for shade can further be identified at parking lots close to the main entrance when this area is surrounded by *M. elengi* and *P. longifolia*(Figure 4k), while a row of *P. macarthurii*, *C. lutescens*, *C. nucifera* and *M. indica* gives a shading effect to the prayer hall/musollah from afternoon sunlight (Figure 4l).



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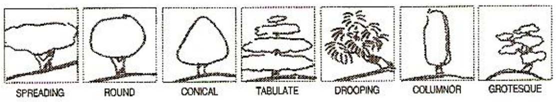
No.	Botanical name	Common name	Height (m) [1]	Form [2]	Symbol
Trees					
1.	*Pterocarpus indicus*	Angsana, Sena	30	Spreading	A
2.	*Ficus benjamina*	Weeping Fig, Benjamin's Fig, Ficus Tree, Waring, Beringin, Ara Beringin	24	Dropping	B
3.	*Juniperus chinensis*	Blue Juniper	10-15	Conical	C
4.	*Thuja orientalis*	Thuja, White Cedar, Yellow Cedar	< 10	Conical	D
5.	*Durio zibethinus*	Durian	25	Spreading	E [3]
6.	*Syzgium samarangense*	Wax Apple, Love Apple, Java Apple, Water Apple, Mountain Apple, Jambu Air	12	Conical	F [3]
7.	*Mesua ferrea*	Ceylon Ironwood, Penaga, Penaga Lilin, Ironwood Tree, Lenggapus	20	Conical/ Round	G
8.	*Bambusa sp.*	Bamboo, Buluh	12-30	-	H
9.	*Macaranga gigentea*	Elephant's Ear, Giant Mahang, Telinga Gajah, Kubin	20	Spreading	I
10.	*Psidium guajava*	Guava, Jambu Batu, Jambu Biji	5	Spreading	J [3]
11.	*Mimusops elengi*	Spanish Cherry, Medlar, Bullet Wood, Tanjong, Mengkulah, Mengkulang, Bakul	12	Round	K
12.	*Artocarpus champeden*	Cempedak	15	Conical	L [3]
13.	*Dillenia suffruticosa*	Simpoh Ayer	15	Round	M
14.	*Polyalthia longifolia*	Ashoka Tree, Cemetery Tree, Mempisang	18	Conical	N
15.	*Artocarpus heterophyllus*	Jackfruit, Nangka	17	Conical	O [3]
16.	*Cinnamomum sp.*	Wild Cinnamomum, Kayu Manis, Medang Wangi	12-15	Round	P
17.	*Mangifera indica*	Indian Mango, Mangga, Mempelam, Pauh	27	Conical	Q [3]
18.	*Araucaria excelsa*	Klinky Pine, Norfolk Island Pine, Cemara	33	Dropping	R
19.	*Dimocarpus longan*	Longan, Mata Kucing	6-7	Spreading	S [3]
20.	*Ravenala madagascariensis*	Traveller's Tree, Traveller's Palm, Pisang Kipas	7	-	T

Figure 3. Landscape plan of CS-B (with reference to Said et al. 2004; LaFrankie 2010; Jabatan Perangkaan Bandar dan Desa 1995).

No.	Botanical name	Common name	Height (m) [1]	Form [2]	Symbol
Trees					
21.	*Averrhoa carambola*	Starfruit, Belimbing Besi	5-8	Round	U [3]
22.	*Manilkara kauki*	Ciku, Sawai, Sawah, Wawoh, Sau	12	Conical	V [3]
23.	*Punica granatum*	Pomegranate, Delima	5-8	Dropping	W [3]
24.	*Citrus sp.*	Lime, Limau	5-8	Round/ Spreading	X [3]
25.	*Acacia auriculiformis*	Acacia-Tree, Wattle, Akasia Kuning,	17	Round	Y
26.	*Phyllanthus acidus*	Malay Gooseberry, Otaheiti Gooseberry, Ceremai, Chermai	10	Spreading	Z [3]
27.	*Vitex sp.*	Leban, Lenggundi, Lagundi, Legundi, Demundi, Muning, Lemuning	5-20	Spreading	AA
28.	*Nephelium lappaceum*	Rambutan	15	Spreading	AB [3]
29.	*Jacaranda obtusifolia*	Jacaranda, Jambul Merak	13	Spreading	AC
Palms					
30.	*Elaeis guineensis*	African Oil Palm, Kelapa Sawit	>9	-	AD
31.	*Cocos nucifera*	Coconut, Kelapa	> 9	-	AE
32.	*Cyrtostachys lakka*	Sealing Wax Palm, Pinang Merah,	3-9	-	AF
33.	*Caryota mitis*	Clustered Fish Tail Palm, Rabok, Beridin, Dudok	3-9	-	AG
34.	*Chrysalidocarpus lutescens*	Butterfly Palm, Area Palm, Golden Fruit Palm	<3	-	AH
35.	*Roystonea regia*	Cuban Royal Palm, Florida Royal Palm, Royal Palm	>9	-	AI
36.	*Rhapis excelsa*	Broadleaf Lady Palm, Bamboo Palm, Rafis Besar	4	-	AJ
37.	*Ptychosperma macarthurii*	Mac arthur's Palm, Cluster Palm, Hurricane Palm	3-9	-	AK
38.	*Archontophoenixalexandrae*	King Palm, Alexander Palm, King Alexander Palm, Nothern Bungalow Palm	25	-	AL
39.	*Veitchia merrilli*	Manila Palm, Christmas Palm, Kerpis Palm, Palma Manila	<3	-	AM

Note:

1 Typical/Average matured height

2


3 Fruit tree

Figure 3, continued.

a).A court between residential block and the shading effect of adjacent residential buildings and slopes

b).*S. samarangense* were planted between Block A and B, Block D and E

c).A row of *V. merrilli* and *P. macarthurii* at certain areas around the sports court

d).A row of *C. lakka* and *P. longifolia* along with Block A

e).A row of *C. nucifera* together with *P. macarthurii*, *D. zibethinus* and *P. indicus* by the side of Block C

f).A row of *C. mitis*, *V. merrilli*, *Citrus sp.*, *P. granatum* and *P. guajava* at the side of Block F

Figure 4. Landscape images of CS-B.


g).Block A and Block E especially at the end of the block is shaded with a row of *D. suffruticosa* and *A. auriculiformis* which planted at the outside of CS-B area at higher altitude


h).A row of *J. chinensis* at the north area


i).*D. suffruticosa* and *A. auriculiformis* at the south area


j).*P. indicus* and *C. lakka* at the east area


k).*M. elengi* and *P. longifolia* at surrounding of parking lots


l).A row of *P. macarthurii*, *C. lutescens*, *C. nucifera* and *M. indica* in front of prayer hall/musollah.

Figure 4, continued.

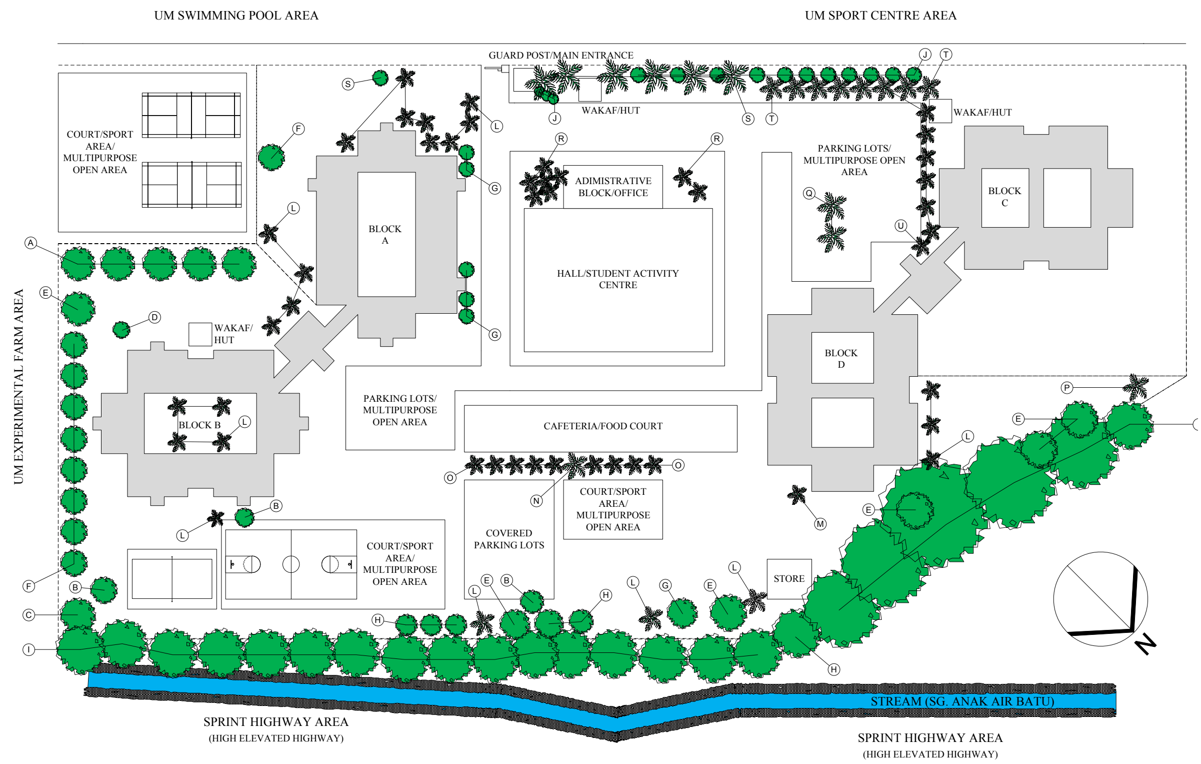
Landscape of CS-C

Noted as a new residential college on campus which established in 1997, there is only a small area covered by trees especially at the northeast boundary. This area plays a role as a buffer zone between the residential area and the Anak Batu River. CS-C has the smallest BAF 0.580 with the lowest ratio of soft and hard landscape areas (58:42) compared to the other two residential colleges. The landscape plan of CS-C is presented in Figure 5.

A typical scene of the village house compound is shown at CS-C when the green area is dominated by the fruit trees and palms. A row of *S. samarangense*, *N. lappaceum* and *G. manggostana* were planted as a borderline between CS-C area and the experimental farm, as well as tennis courts even though there is a chain link fence (Figure 6a& b). All these trees are still small and incapable of providing shelter from the sun for the residential building. Some parts of Block B, particularly facing the east receive high radiation from excessive morning sunlight and is the hottest area in CS-C (Figure 6c). The presence of a high elevated highway, SPRINT Highway on the northeast, gives shade to the court and other multipurpose areas located nearby.

A row of *B. nobilis* and *A. alexandrae* at the front area is able to give a shading effect to the administrative block (Figure 6d)whereas Block C is freely exposed to solar radiation from the west in the early afternoon (Figure 6e). Nevertheless, the large double storey buildings of the Sport Centre on the elevated ground opposite to Block C shorten the duration of exposure. The open space which also houses the parking lots next to Block C and D were shaded by two *E. guineensis*(Figure 6f). Whilst, a group of *C. nucifera* which was planted near the administrative block only gives an aesthetic value to that area (Figure 6g).

The trees of *Leucaena sp.* which grows at the buffer zone between residential areas and AnakBatu River gives a significant shading effect to the some part of Block D especially for the room that faces the north (Figure 6h). The tree canopies cover the ground and directly reduce the temperature, whereas the presence of *A. alexandrae*, *L. grandis* and *N. lappaceum* enhance the absorption of excessive radiation (Figure 6i). Theoretically, this area is the coolest area with high humidity in the CS-C area.



Direction: +3° 7' 44.86", +101° 39' 38.75" (3.129128, 101.660764)

No.	Botanical name	Common name	Height (m) [1]	Form [2]	Symbol
Trees					
1.	*Garcinia manggostana*	Mangosteen, Manggis, Mesetor, Sementah, Semetah	18	Conical	A [3]
2.	*Mangifera indica*	Indian Mango, Mangga, Mempelam, Pauh	27	Conical	B [3]
3.	*Bambusa sp.*	Bamboo, Buluh	12-30	-	C
4.	*Bauhinia purpurea*	Orchid Tree, Tapak Kuda	8	Dropping	D
5.	*Nephelium lappaceum*	Rambutan	15	Spreading	E [3]
6.	*Syzgium samarangense*	Wax Apple, Love Apple, Java Apple, Water Apple, Mountain Apple, Jambu Air	12	Conical	F [3]
7.	*Ficus benjamina*	Weeping Fig, Benjamin's Fig, Ficus Tree, Waring, Beringin, Ara Beringin	24	Dropping	G
8.	*Macaranga gigentea*	Elephant's Ear, Giant Mahang,Telinga Gajah, Kubin	20	Spreading	H
9.	*Leucaena sp.*	Petai Belalang, Petai Jawa, Petai Belanda, Petai Tiga Bulan	10	Spreading	I
10.	*Mesua ferrea*	Ceylon Ironwood, Penaga, Penaga Lilin, Ironwood Tree, Lenggapus	20	Conical/Round	J
11.	*Punica granatum*	Pomegranate, Delima	5-8	Dropping	K [3]
Palms					
12.	*Ptychosperma macarthurii*	Mac arthur's Palm, Cluster Palm, Hurricane Palm	3-9	-	L
13.	*Chrysalidocarpus lutescens*	Butterfly Palm, Area Palm, Golden Fruit Palm	<3	-	M
14.	*Caryota mitis*	Clustered Fish Tail Palm, Rabok, Beridin, Dudok	3-9	-	N
15.	*Cyrtostachys lakka*	Sealing Wax Palm, Pinang Merah	3-9	-	O
16.	*Licuala grandis*	Fan Palm, Palas Kipas	<3	-	P
17.	*Elaeis guineensis*	African Oil Palm, Kelapa Sawit	>9	-	Q
18.	*Cocos nucifera*	Coconut, Kelapa	> 9	-	R
19.	*Bismarckia nobilis*	Bismark Palm	10	-	S

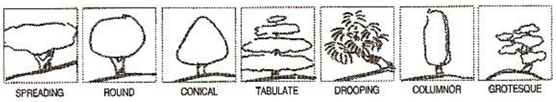
Figure 5. Landscape plan of CS-C (with reference to Said et al. 2004; LaFrankie 2010; Jabatan Perangkaan Bandar dan Desa 1995).

No.	Botanical name	Common name	Height (m) [1]	Form [2]	Symbol
Palms					
20.	*Roystonea regia*	Cuban Royal Palm, Florida Royal Palm, Royal Palm	>9	-	T
21.	*Veitchia merrilli*	Manila Palm, Christmas Palm, Kerpis Palm, Palma Manila	<3	-	U

Note:
Note:

1 Typical/Average matured height

2



3 Fruit tree

Figure 5, continued.

a).A row of *S. samarangense*, *N. lappaceum* and *G. manggostana* were planted as a boundary

c).Block B; particularly that facing to the east, receive high radiation from excessive morning sunlight and defined as the hottest area in 11^{th} RC

b).A row of *S. samarangense*, *N. lappaceum* and *G. manggostana* were planted as a boundary

d).A row of *B. nobilis*, and *A. alexandrae* at the front area

Figure 6. Landscape images of CS-B.

e).Block C is freely exposed to solar radiation from the west in the early afternoon

h).The *Leucaena sp.*tree which grows at the buffer zone between the residential area and Anak Batu River

f).The open space which also parking lots were shaded by two *E. guineensis*)

i).the presence of *A. alexandrae*, *L. grandis* and *N. lappaceum* enhance the absorption of excessive radiation

g).A group of *C. nucifera* which planted near to the administrative block

Figure 6, continued.

Conclusions

Initially, CS-A has a big potential to achieve sustainable development according to performance criteria UE 3 - Urban greenery and environmental quality. There are diversities of mature tree species that help to increase the rate of carbon sequestration, although CS-B has the highest percentage of green open space, which is only based on the BAF, as well as ratio of soft and hard landscape area. As a new residential college on campus, the numbers of tree and vegetation coverage area at CS-C is still small compared to CS-A and CS-B. Thus, fast growing, decorative and low-maintenance types of vegetation have been broadly planted at CS-C area in creating a sustainable environment. Due to the high achievement of CS-A in sub-criteria UE 3-3, it has increased the percentage of green open space and provided natural restoration of carbon by improving urban biodiversity through preservation and conservation of the natural environment, which are the sub-criteria for UE 3-1 and UE 3-2.

The acceptance, suitability and effectiveness of tropical forest trees in residential college landscapes have been accepted to the old residential colleges, CS-A is dominated by tropical forest trees. There are *C. inophyllum*, *M. atropurpurea*, *P. pterocarpum* and *L. floribunda*. With large crowns and decent growth rates, these types of trees are able to provide shade to the building from excessive sunlight penetration, which reduces the cooling cost of the building and improves urban air quality (Akbari et al. 2001; Jamaludin et al. 2011). Moreover, the selection of tropical forest trees is a key to successfully improving urban green infrastructure (Thaiutsa et al. 2008). According to KeTTHA (2011), one hectare of tropical forest absorbs 4.3 tCO_2/year to 6.5 tCO_2/year, whilst one tree absorbs approximately 1,000 kg of CO_2. Regrettably, through observation, the cleaning work of fallen leaves become a long term issue.

The trees of *D. suffruticosa* is widely used as a border or natural fences when this species is a large, evergreen shrub with continuous yellow flowers and can easily be grown especially in swampy ground (Corner 1998). Unfortunately, this species is wildly grown and indirectly creates a small secondary forest at the border area of CS-A and CS-B.

Then, to generate a village scene and living environment in an urban area of Kuala Lumpur, fruit plants such as *D. zibethinus, S. samarangense, N. lappaceum, G. manggostana, A. champeden, A. heterophyllus, M. indica, P. guajava, D. longan, A. carambola, M. kauki, P. grantum,* and *Citrus sp.* have been used in the landscape of residential colleges which were built in the 1980s onwards, such as CS-B and CS-C. With new hybrids and the development of synthetic seeds of fruit tree species, plant disease resistance was increased and it helps to lower the maintenance and able to establish a large canopy of trees in a shorter duration (Roberts 2007; Rai et al. 2009).

Palms were most extensively cultivated in the landscape of residential colleges when these types of trees are easy to take off, able to survive in various condition of climate and possess prominent leaves with a characteristic shape (Jones 1995; Stewart 1994) which provides a shelter from the direct sunlight. Thus, it helps to maintain the humidity level and lowers the water requirement which directly creates microclimates within the landscape area by encouraging partial shade and full shade trees to grow (Bergman 2011). Aesthetically, the *E. guineensis* was also used in the residential college landscape. The mature trees able to provide a dense canopy which creates a heterogeneous habitat (Luskin and Potts 2011).

The trunk offers conditions for bird's nest ferns, *Aspleniumnidus* to grow and provide a stable microclimate in a hot and dry area (Fayle et al. 2010).As the world's largest producer and exporter of palm oil (Sumati et al. 2008), this tree became a part of national identity.

The *Leucaena sp.* is a suitable tree in the buffer zone between residential college areas and river side as ability to grip the ground and provide stability in the bank/slopes. This tree increases soil penetrability and shear strength in accommodating the maximum pressure without rupture due to the outstanding biomass and extensive root system (Osman and Barakbah 2011). Moreover, it gives a significant shelter and shading to the building classified as fast growing tree and needed least maintenance compared to the other trees. The same potential was also discovered with *P. indicus* where the tree has excellent potential for windbreaks planting where space permits, soil stabilization, especially along drainage lines and flood plains, due to its adaptation to such sites, large buttresses, and extensive, spreading, near-surface root systems (Thomson 2006). Unfortunately, cleaning work of fallen leaves will become an issue.

Principally, the comparison of shading effect among three residential colleges is not appropriately made due to differences in the year of establishment. Most of the trees at CS-A already mature with a dense of canopy and able to provide shading effect to the residential buildings. However, the landscape setting at CS-A can be well adapted at CS-B and CS-C where the tropical forest trees with high densities of the canopy were planted nearer to the residential building especially the building with east-west orientation. The new hybrid and synthetic seeds of tropical forest tree hypothesised the acceleration of growth and maturity of the tree. Thus, expand the use of tropical forest tree in the landscape especially in urban areas. Referring to the landscape setting at CS-B and CS-C, emphasis has been given in the boundary areas. The greatest numbers of ornamental trees were planted nearer to the building which the height of the tree is not sufficient in providing shading effect to the building. In fact, the effectiveness of landscape in providing shade to the building will require a long time, especially in high-rise buildings. Therefore, buildings should essentially design to incorporate elements of the landscape such as the use of green wall and rooftop garden.

In summary, there are many improvements at residential college landscapes in urban area towards sustainable development. The empty spaces, especially between the residential buildings should be planted with high rate of carbon sequestration trees that are also capable to give shade in reducing solar penetration.

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